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Environmental effects of energy policy in sicily: The role of renewable energy

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Abstract

The saving of primary energy from fossil fuels and the promotion of exploitation of renewable sources are two of the most relevant goals to be achieved in order to match the climate protection target fixed by the Kyoto Protocol in 1997. For Italy, the commitment is the reduction of the greenhouse emissions by 6.5% below 1990 levels over the commitment period 2008–2012.

It requires the introduction of suitable political strategies and programmes aimed to establish a sustainable energy system together with the application of a set of actions either at national scale, either at regional one. This study presents the results of a survey in the context of the Regione Sicilia about the potential saving of primary energy and the reduction of greenhouse emissions, which should be allowed by local energy planning in the energy uses. An assessment of the specific costs per unit of saved energy and of avoided CO_{2eq} emissions is presented for each of the actions of the Sicily Regional Energy Master Plan (REMP). The REMP proposal has been presented by the University of Palermo, Messina and Catania together with ITAE-CNR. It is up today under discussion and examination by the Regional Government.

Keywords: Renewable sources; Energy planning; Kyoto protocol; Regional energy master plan

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1. Introduction

The combustion of fossil fuels has played a dominating role in the build up of greenhouse gases (GHG) in the atmosphere. It is estimated that the energy sector accounts for about half the global emissions of GHG [1]. During the last 20 years, about three-quarters of the anthropogenic emissions of CO_2 have been due to the fossil fuels burning [2]. About 80% of the world's total use of energy is based on fossil fuels and they play an important role in the transport and stationary energy sectors, including electric power generation [3].

It is essential to develop highly efficient energy utilization processes and substitute energy sources as a countermeasure against CO_2 problem, in addition to the current renewable energy power plants, i.e. hydraulic power plants [4].

Even though conventional sources, such as oil, natural gas and coal meet most of the energy demand at the moment, the role of renewable energy sources and their current advances have to take more relevance in order to contribute to energy supply and support the energy conservation strategy.

Therefore, the energy planner has to convey the border of the system under study towards a smaller context where several constraints of different nature are involved [5].

The increasing concerns on the global environmental effects of CO_2 discharge, resulting from energy uses, as well as the growing energy consumption in developed and developing nations and the consequent fossil sources depletion, make relevant the current role of renewable sources in a regional policy context, and the efforts aiming at replacing oil with Technologies able to exploit Renewable Energy (RET) [6].

Local authorities are called to play a remarkable role in carrying out environmentally oriented strategies to manage energy resources efficiently and to address the life quality towards the sustainability [7]. The local action, at regional level, has to be addressed to promote the RET aimed at reaching the control of environmental impacts by transport, buildings, land use, and sectors of domestic, services and industrial end-use [8].

In particular, in the context of a regional energy policy voted to the introduction of sustainable technologies in the energy power generation, the following categories of measures would encourage the dissemination of RET [9]:

- Implementation of long and medium term programmes of renewable energy policy [10].
- Development and application of carefully selected technological and institutional strategies.

- Start-up of medium term renewable energy training and capacity building programmes.
- Institution of new and flexible financing mechanisms.
- Wider application of innovative dissemination strategies.

Since it is now recognized that the dimension of the environmental protection is relevant in the energy planning policy path for a country [11], this paper analyses the status of the energy planning sector in Sicily and the relative measures to match the Kyoto Protocol (KP) targets, incorporating the specific costs of the saved energy through the RET, and of the relative avoided emissions of CO_{2eq} into the planning process.

2. CO_{2eq} emissions from the Italian energy system

CO_{2eq} represents the most relevant contribution to greenhouse effect, since it represents the 80% of the total emissions of gases taken into account by Kyoto Protocol (KP) [12]. In particular, energy sector is the main source of CO_{2eq} releases. Table 1 shows the distribution of these emissions among the several economic sectors either at National either at Regional scale 1990.

Guidelines and action plans have been defined to comply with the targets fixed in KP. In Italy, the first operative programme was the 'National plan to reduce the greenhouse emissions from 2003 to 2010' introduced by the Ministry for the Environment, accepted through the CIPE Decision No. 123/02 [13]. In this act, two national emissions scenarios have been developed for 2010:

- A 'tendence scenario', in which the amount of emissions derives from policies and actions still in force, applied to the historical trend of the GHG emissions, based on the data from 1990 to 2010 (Table 2);
- A 'reference scenario', which takes into account also the effects of the actions included in the CIPE act (Table 3), including the saving of emissions which can be derived from the flexible mechanisms of KP [Joint Implementation e Clean Development Mechanism,

Table 1
Emissions of GHG from the energy use sector in Italy and Sicily in 1990

Sector	Italy (10^9 kg CO_{2eq}) (1990)	Sicily(10^9 kg CO_{2eq}) (1990)
Energy use:	424.9	39.6
Energy industries:	147.4	21.0
Thermal plant	124.9	13.3
Oil refinement	18.0	6.1
Other	4.5	1.6
Manufacturing industry and building	85.5	6.5
Transport	103.5	6.6
Civil sector	70.2	1.7
Agriculture	9	0.6
Other	9.3	3.2
Other sources	96.1	9.0
Total	521.0	48.6

Table 2
Emissions of GHG from the energy use sector in Italy and Sicily in the tendence scenario (CIPE, 2002)

Sector	Italy (10^9 kg CO_{2eq})	Sicily (10^9 kg CO_{2eq})
Energy use:	484.1	44.9
Energy industries:	170.4	24.7
Thermal plant	150.1	15.8
Oil refinement	19.2	6.6
Other	1.1	2.3
Manufacturing industry and building	80.2	5.1
Transport	142.2	9.0
Civil sector	74.1	1.9
Agriculture	9.6	0.7
Other	7.6	3.5

Table 3
Emissions of GHG from the energy use sector in Italy and Sicily in the reference scenario

Sector	Italy (10^9 kg CO_{2eq})	Sicily (10^9 kg CO_{2eq})
Energy use:	444.5	41.18
Energy industries:	144.4	22.28
Thermal plant	124.1	13.38
Oil refinement	19.2	6.6
Other	1.1	2.3
Manufacturing industry and building	80.2	5.1
Transport	134.7	8.3
Civil sector	68	1.3
Agriculture	9.6	0.7
Other	7.6	3.5

(JI and CDM)] to be applied in the land use sector [Land Use, Land Use Change and Forestry (LULUCF)].

The measures included in the reference scenario do not allow to match the KP within 2010. Therefore, a further reduction of 41.00×10^9 kg CO_{2eq} in Italy, and of nearly 3.80/ 4.00×10^9 kg CO_{2eq} in Sicily are required (Table 4). In other terms National and Regional actions in force or to be implemented in the near future have to overcome the reference scenario in order to fit with the overall target. Actually the CIPE act does not specify Regional targets, being today not clear which commitment and objective every Regional Government has got. For this reason Regional Master Plans emitted in Italy are very heterogeneous and not coordinated.

3. The promotion of the renewable energy sources in the context of Sicily

The recent proposal for a new Energy Master Plan in Sicily has highlighted the achievement of the described target in the Regional energy system requires the

Table 4
Reduction measures of CO_{2eq} emissions

Energy uses	Italy (10^3 kg CO_{2eq}/y)	Sicily (10^3 kg CO_{2eq}/y)
Electric sector	26.00	3.00
Civil sector	6.30	0.60
Transport	7.50	0.70
Total national measures	**39.80**	**6.76**
Carbon credits from *JI* and *CDM* mechanisms	12	
Further reduction not included in (CIPE, 2002)	41.00	3.8/4

implementation of many concurrent actions [14]:

- significant increase of the exploitation of local renewable energy sources, by means of the diffusion of the RET either in the energy power generation either in the different energy uses;
- improvement of the efficiency in the energy power production by the renovation of the existing power plants;
- reduction of the energy consumption in the sectors of industry, residential, agriculture and transport by the improvement of the efficiency and the use of CHP systems.

Due to the favourable climatic conditions, Sicily has a very high potential of renewable sources exploitation (solar and wind power in particular).

In such a context, the employment of the renewable sources represents big opportunity in order to reduce the environmental impact of the regional energy uses, together with a significant economic and social follow-up.

Up today the Regional Energy Master Plan (REMP), which is under discussion and examination by the Regional Government, takes into account a set of specific actions for the diffusion of RET, but its practical implementation requires the support of financing resources. A relevant share of funding could derive by the already available amount of the European Regional Development Funds. Such funds, especially addressed to the less developed areas of the UE, aim to encourage these regions to invest in innovation and technological improvement, reducing the lag in their development and enhancing their competitiveness.

The Sicily Regional Government has adopted a strategic plan to achieve the above targets. This Regional Operative Plan (ROP), in its parts dealing with energy and environmental resources, essentially aims to integrate energy policy with environmental strategies, so that the conversion of energy systems towards clean technologies could match the national objective of renewable sources promotion.

In particular, the 1.17th strategy of the ROP about 'diversification of the energy production' aims to encourage the renewable sources use for the energy power generation in Sicily, in order to reduce the primary energy consumption and the GHG emissions. Such strategy is addressed to achieve the following objectives [15]:

- A sustainable system of the energy distribution, which could allow to improve the life quality of urban areas and the performance of the production system;

Table 5
Public resources and private financing for RET

Technology	Public 10^6 €	%
Wind		
On-shore	25.00	29
Off-shore	11.67	14
Biomass	29.17	34
Solar photovoltaic	19.17	23
Total	85.01	100

- The generation of energy power from renewable sources, acting on the enterprises system, by means of specific financial aids.

In detail the Sicily Regional Government makes provision for the following investments:

- wind farms with a nominal power of 200 MW;
- biomass plants with a power of 60 MW;
- photovoltaic panels with a total power of 5 MW;

No objectives are fixed either for thermal uses of solar energy nor for exploitation of geothermal energy. In particular, public financing for ROP targets is supplied, as a complement of private investments. Table 5 shows a detailed list of public financial resources, for a total financing of ∊ 85,010,000, not including solar thermal and geothermal energy.

Starting from this first objectives, significant additional goals are today listed in the first draft of the REMP with a special focus on wind energy, and solar thermal and biomass.

4. Definition of the actions and the assessed scenarios in the REMP proposal

Three strategic goals has been declared as objectives of the Italian energy policy. They are:

- Goal 1: The CO_{2eq} emissions by the Sicilian energy uses should be reduced of 8.30×10^9 kg.
- Goal 2: The power energy production through RET will share in the gross inner consumption of electric power, for the 25% within 2010 [16].
- Goal 3: The primary energy saving accomplished through RET will share in the gross inner consumption, according to the 12% within 2010 [17].

The REMP contains a set of action voted to contribute to the fulfilment of these goal at Regional scale. Tables 6–9 show the actions enclosed in the Regional energy policy, according to four time-based scenarios:

- S1: REMP actions that have been already financed;
- S2: REMP short period actions at 2006 (short period);
- S3: REMP actions at 2010 (medium period);
- S4: actions voted to fulfil ROP targets.

Table 6
Fixed actions in S1

S1 actions	Power (MW)
Photovoltaic panels	10
Wind farms	123
Biomass	125
	Installed surface (m^2)
Solar thermal	70,000

Table 7
Fixed actions in S2

S2 Actions	Power (MW)
Photovoltaic panels	3.55
Wind farms	
Action 1: Plan of utilization and activation of authorized plants	400
Biomass	Fossil Fuels saving [MWh/y]
Action 1: Activations of 12 collection points	201,000.56
Action 2: Activation of 6 collection points for forestall wastes	26,000.74
Action 3: Utilization of zootechnical wastes	88,000.00
Solar thermal	Installed surface (m^2)
Action 1: Residential	233,333
Action 2: Hotels and large demands	25,000
Action 3: Solar cooling	1,786

Table 8
Fixed actions in S3

S3 actions	Power (MW)	
Photovoltaic	3.91	
Wind		
Action: Activation of 'Districts with high generation of wind energy'	500	
Biomass	Fossil Fuels saving [MWh/y]	Power [MW]
Action 1: Activation of 20 collection points	331,000.20	
Action 2: Energy power generation from zootechnical wastes	65,000.70	13,000.70
Solar thermal	Installed surface [M^2]	
Action 1: Residential	400,000	
Action 2: Hotels and large demands	50,000	
Action 3: Solar cooling	41,667	

Table 9
Fixed actions in S4

S4 actions	Power (MW)
Photovoltaic	5
Wind	200
Biomas	60

The efficacy of such actions has been assessed by the achievable saving of primary energy and the avoided emissions of CO_{2eq}.

5. Energy saving and avoided emissions of CO_{2eq}

Table 10 shows the emission factors of CO_{2eq}, which are estimated for the thermoelectric generation in Sicily, and for the RET construction. The production in 2000 is assumed for the calculation of the emission factors [18]. The energy power generation and the relative CO_{2eq} emissions essentially depends on the actual technology of power plants, which are mostly characterized by the use of oil (Table 11).

The emission factor of the thermoelectric energy power is derived for a giga-joule of energy power generated in the specified geographical context [19]. It is calculated as follows:

$$e_{\mathrm{j}} = \frac{m_{\mathrm{CO2eq}}}{P_{\mathrm{j}}} \tag{1}$$

where e_j is the emission factor of CO_{2eq} (10^3 kg/GJ), m_{CO2eq} represents the amount of CO_{2eq} released in the specified year, (10^3 kg/year), Pj is the energy power production in the specified year (GJ/year).

For each scenario the calculation of the CO_{2eq} emission factor is extended to the construction and operation stages of the power plants.

In particular, with regard to the renewable energy plants, gas emissions are assumed null during the operation time. The CO_{2eq} balance is assumed null for the biomass, since during its combustion it returns the CO_{2eq} which has been absorbed during its growth. That implies a combustion without greenhouse effect. The CO_{2eq} emission factors are calculated referring to existing plants and the following life times have been fixed:

- 20 years for photovoltaic panels [20,21];
- 20 years for wind farms [22,23];
- 25 years for biomass plants [24,25].

In detail, each item is estimated accounting its CO_{2eq} emissions from the plant construction step to the energy production in the overall life cycle. Such emission factors have been compared with average values provided by well known environmental databases [26,27].

Tables 12–14 show the efficacy of the forecasted actions in the Sicily energy planning. The accomplishment of such actions could allow the following results:

- 24.23% for the goal 1;
- 46.20% for the goal 2;
- 45.04% for the goal 3.

Table 10
CO_{2eq} emission factor

CO_{2eq} emissions	Thermoelectric (10^3 kg CO_{2eq}/GJ)	Photovoltaic (10^3 kg CO_{2eq}/GJ)	Wind (10^3 kgCO_{2eq}/GJ)	Biomass (10^3 kgCO_{2eq}/GJ)
Construction step	0.008	0.015	0.003	0.0018
Operation step	0.158			

Table 11
Sicilian energy mix in 2000

Technology	Energy power generation at 2000 (GJ/year)
Hydro	2,900,160
Thermoelectric by oil	88,180,200
Wind/Photovoltaic	360
Total	91,080,720

It must be stressed that these figures are referred only to the contribution given by RET, and do not take into account other typologies of interventions on the field of energy efficiency, generation and uses.

With regard to the saving of primary energy and electric energy, the forecasted contribution of renewable energy sources is not able to fit the current international targets within 2010 (Goal 2 and Goal 3). The main reason of this fact is due to the relatively small contribution given by hydroelectric generation in Sicily (3.2%) compared to the high share recorded in Italy (18.4%). Being not effective nor environmental affordable a further exploitation of hydro power in Sicily, the most important role must be played by wind energy that implies either relevant environmental and technological concerns.

It can be noted that in terms of avoided emissions through the use of renewable energy sources (see Table 13), the expected outcome of 0.87×10^9 kgCO_{2eq}/y in the medium period (Scenario S3) is widely higher than the corresponding Regional minimum target of 0.60×10^9 kgCO_{2eq}/y within 2010 fixed by the CIPE act (Table 15).

Taking into account the global effect of the assessed scenarios the overall contribution to the emission reduction by the renewable energy sources increases to 2.01×10^9 kgCO_{2eq}/y. The total contribution to the objectives fixed in the Regional energy policy, shared by RET are shown in Figs. 1–3. In detail Fig. 1 shows the share of each renewable energy sources to the reduction of CO_{2eq} emissions, while Figs. 2 and 3 show the global contribution of each renewable energy sources to the forecasted outcomes for the saving of primary energy and electric energy.

6. Assessment of the costs of the saved energy and avoided emissions costs

On the basis of the required investment and of the available financing resources, it is relevant to analyse the cost of such benefits. In detail, the costs of the saved energy in €/GJ and of the avoided CO_{2eq} emissions are measured in €/10^3 kg, referred to public funding required to support each action and to realise or improve the current energy network.

Table 12
Energy saving by the RES in all the compared scenarios

RES	S1		S2		S3		S4	
	Yearly saved energy (GJ/y)	Life time saved energy (GJ)	Yearly saved energy (GJ/y)	Life time saved energy (GJ)	Yearly saved energy (GJ/y)	Life time saved energy (GJ)	Yearly saved energy (GJ/y)	Life time saved energy (GJ)
Photovoltaic panels	56,808	1,420,200	20,167	504,171	22,212	555,298	28,404	710,100
Wind farms	708,480	17,712,000	2,304,000	57,600,000	2,880,000	72,000,000	1,152,000	28,800,000
Biomass	33,113	827,820	1,311,480	32,787,000	1,428,520,603	35,713,015	15,894,144	39,735,360
Solar thermal	208,629	5,215,718	435,338	10,883,440	1,644,252,86	41,106,32		
Total	1,007,030	25,175,738	2,759,505	101,774,611	5,974,985,39	149,374,635	27,698,184	69,245,460

Table 13
Avoided CO_{2eq} emissions by the RET in all the compared scenarios

RES	S1		S2		S3		S4	
	Yearly avoided emissions (10^3 kg CO_2/y)	Life time avoided emissions	Yearly avoided emissions (10^3 kg CO_2/y)	Life time avoided emissions	Yearly avoided emissions (10^3 kg CO_2/y)	Life time avoided emissions	Yearly avoided emissions (10^3 kg CO_2/y)	Life time avoided emissions
Photovoltaic panels	8.95×10^3	2.24×10^5	3.18×10^3	7.95×10^4	3.50×10^3	8.75×10^4	4.48×10^3	1.12×10^5
Wind farms	1.12×10^5	2.79×10^6	3.63×10^5	9.08×10^6	4.54×10^5	1.13×10^7	1.82×10^5	4.54×10^6
Biomass	5.22×10^3	1.30×10^5	1.22×10^5	3.05×10^6	2.88×10^5	3.60×10^6	2.51×10^5	6.26×10^6
Solar thermal	2.52×10^4	6.29×10^5	6.86×10^4	1.72×10^6	1.21×10^5	3.02×10^6		
Total	1.51×10^5	3.78×10^6	5.57×10^5	1.39×10^7	8.66×10^5	1.81×10^7	4.37×10^5	1.09×10^7

Table 14
Efficacy of the scenarios with regards the fixed goals

Goal	S1 + S2 Short period (%)	S3 Medium period (%)	ROP (%)	Total actions (%)
KP target	8.53	10.44	5.26	24.23
Directive 2001/77/ce	13.84	22.38	9.98	46.20
Green paper	13.56	22.59	8.89	45.04

Table 15
Measures of reduction included in the reference scenario of the CIPE act (CIPE, 2002)

Energy uses	Italy (10^9 kg CO_{2eq}/y)	Sicily (10^9 kg CO_{2eq}/y)
Electric sector	**26**	**3**
CC Expansion for 300 MW	8.9	0.83
Expansion of import capacity for 2300 MW	10.6	
Growth of renewable energy sources up to 2800 MW	6.5	0.60
Civil sector	**6.3**	**0.60**
Efficiency of end uses	6.3	0.60
Transport	7.5	0.70
Carbon credits from JI and CDM	12	
Total measures (CIPE, 2002)	**51.8**	**4.30**
Further reduction not included in (CIPE, 2002)	41.00	4.00
Total	**92.8**	**8.30**

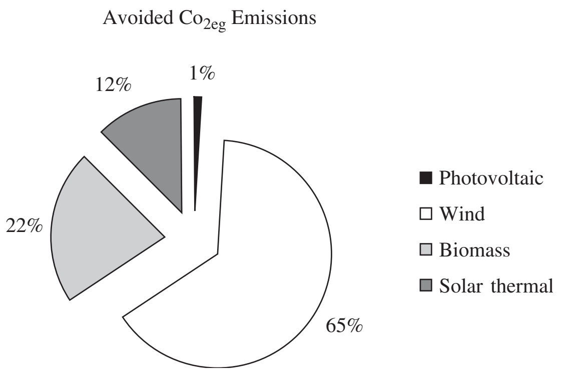


Fig. 1. Global contribution of the assessed scenarios to the reduction of CO_{2eq} emissions, shared by RET.

Tables 16–19 show the allocation of the cost of the saved energy among the RET to introduce in the energy power generation, for all the assessed scenarios. It results that the PV involves the highest specific cost among the assessed RET, regarding both the saved energy and the avoided CO_{2eq} emissions, while the wind farms involve the lowest specific costs in the assessed scenarios.

In particular it should be noted that wind energy still today does not require public funding support, being already cost-efficient. On the other hand, public funding

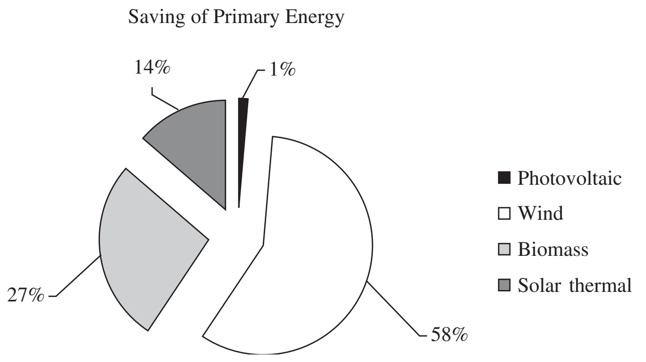


Fig. 2. Global contribution of the assessed scenarios to the primary energy saving, shared by RET.

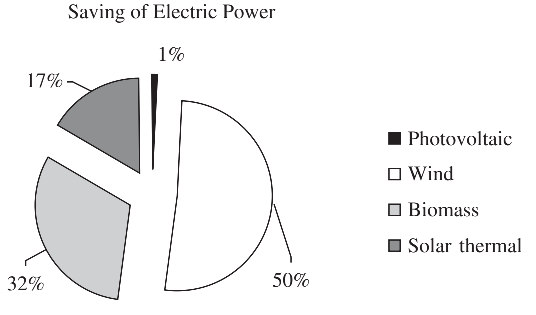


Fig. 3. Global contribution of the assessed scenarios to the saving of the electric power, shared by RET.

Table 16
Cost allocation among the RET in S1

RET	Public financing (€)	Cost of saved energy (€/GJ)	Cost of avoided CO_2 emissions (€/10^3 kg)
Photovoltaic	59,319,000	41.77	264.97
Wind	21,328,000	1.20	7.64
Biomass	1,660,000	2.01	16.69
Solar thermal	10,500,000	2.01	12.72
Total	92,807,000		

are required for the restructuring of the electricity network and for the management of the grid.

7. Conclusions

As a consequence of the growing interest on the environmental effects of CO_{2eq} emissions, resulting from energy uses, the Community policy is voted to the integration of

Table 17
Cost allocation among the RET in S2

RET	Public financing (€)	Cost of saved energy (€/GJ)	Cost of avoided CO_2 emissions (€/10^3 kg)
Photovoltaic panels	20,000,000	39.67	251.66
Wind farms	28,560,000	0.50	3.14
Biomass			
Action 1: Activation of 12 collection points	20,000,000	1.10	13.23
Action 2: 6 Activation of collection points for forest wastes	24,500,000	1.87	22.44
Action 3: Utilization of zootechnical wastes	5,000	0.41	3.73
Solar thermal			
Action 1: residential	35,000,000	3.26	20.70
Action 2: Hotels and large demands	3,562,500	26.31	167.26
Action 3: Solar cooling	1,500,000	75.72	481.43
Total	118,122,500		

Table 18
Cost allocation among the RET in S3

RET	Public financing (€)	Cost of saved energy (€/GJ)	Cost of avoided CO_2 emissions (€/10^3 kg)
Photovoltaic panels	15,000,000	27.01	171.36
Wind farms	0.00	0.00	0.00
Biomass			
Action 1: Activation of 20 collection points for forest wastes	30,000,000	1.01	12.08
Action 3: Utilization of zootechnical wastes	22,877,500	3.87	20.50
Solar thermal			
Action 1: Residential	21,000,000	0.65	8.23
Action 2: Hotels and large demands	4,000,000	0.97	18.48
Action 3: Solar cooling	15,000,000	3.27	60.11
Total	107,877,500		

the environmental considerations with the energy planning sector. In fact, according to the current European and National guideline toward the concept of the sustainable development, the increase of local renewable energy sources should become the highlights of energy planning.

Table 19
Cost allocation among the RET in S4

RET	Saved primary energy (GJ)	Cost of saved energy (€/GJ)	Cost of avoided CO_2 emissions (€/10^3 kg)
Photovoltaic Panels	19,170,000	27.00	171.26
Wind farms	36,670,000	1.27	8.10
Biomass	29,170,000	0.73	4.66
Total	85,010,000		

In response to such requirements, the introduction of suitable planning policies and programmes must be supported to establish a sustainable energy system together with the application of a set of actions either at national scale, either at regional one.

This paper focuses on the current and proposed Sicily planning on the energy uses, carrying out a detailed analysis of the actions and of the forecasted objectives fixed in the REMP proposal. The efficacy of these actions is assessed as: (i) the achievable saving of energy; and (ii) the avoided emissions of CO_{2eq}, which can be fulfilled through the contribution given by RET. In addition, such items are compared with three strategic Community goals: (i) the CO_{2eq} emissions by the Italian energy uses should be reduced of 6.5%below1990 levels in order to match the KP; (ii) the renewable energy sources will share in the gross inner consumption of electric power, for the 25%within 2010; (iii) the renewable energy sources will share in the gross inner consumption, for the 12% within 2010.

As the results show, on one hand the implemented actions involve an overall contribution to the CO_{2eq} reduction in the medium period, which is widely higher than the corresponding Regional minimum target fixed by the CIPE act to match the KP. On the other hand, such actions are not sufficient for matching the fixed targets on the energy saving, if the other typologies of interventions on the field of energy efficiency, generation and uses are not implemented.

The achievement of the above goals is strongly connected to the financing support by the public subjects, since several technologic and prescriptive constraints make difficult the development of renewable energy sources. Among these ones, the high cost of production is certainly one of the most relevant. In this sense, the reduction of these constraints represents the initial measure to be adopted in order to support the renewable energy exploitation. On the other hand, every diffusion action should be implemented in a framework of a new institutional context (which allows to reduce market risks), and of simplification of the bureaucratic course.

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